THE GEOLOGICAL STRUCTURE OF THE HOUSATONIC VALLEY LYING EAST OF MOUNT WASHINGTON.[1]

(With Plates V, VI, VII.)

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CONTENTS.

IN a former paper[2] I have discussed the geological structure of Mount Washington and shown that in that mass we have to deal with a conformable series of beds embracing four distinct lithological members. These members are: (1) a lower dolomitic limestone—the Canaan Dolomite; (2) a lower schist member containing usually abundant garnets and frequently also staurolite—the Riga Schist; (3) a calcareous member, in the valley a marble but on the summit plain of the mountain and along its base very micaceous and graphitic—the Egremont Limestone; and (4) a schist member very feldspathic and

[1] Part of a report of work done as Assistant Geologist in the Archean Division of the U. S. Geological Survey, under the direction of Professor Raphael Pumpelly.

[2] On the Geological Structure of the Mount Washington Mass in the Taconic Range. Journal of Geology, Vol. I., p. 717.

usually either chloritic or sericitic, but always free from garnets and staurolite—the Everett Schist.

The area studied.—To the eastward of Mt. Washington, at a distance of five or six miles, flows the Housatonic river, its general course being like the crest-line of the mountain, nearly south. To the northeastward of the mountain the intervening area is a nearly level plain in which are extensive outcrops of the Egremont Limestone, sometimes with thin intercalated micaceous or quartzitic layers. This limestone belt extends almost to the river at Great Barrington and Sheffield Plain. South of the village of Sheffield, however, the level expanse of the plain is broken by the occurrence along its eastern margin of low, sharp ridges trending northeasterly to northwesterly, and increasing in number as well as in height and breadth in going south. The area covered by these ridges begins at Sheffield where two narrow ridges are separated by only a few hundred feet, and broadens steadily in going southward, thus narrowing the belt of limestone on its western border, and finally cutting it off near the village of Salisbury by making connection with the southeastern base of Mt. Washington. (Cf. Plate III. of Mt. Washington paper). Corresponding with the increase in breadth which characterizes the area in its southern portion, there is a marked increase both in the height and the width of the individual ridges. East of the Twin Lakes in Salisbury is Tom's Hill, which rises to a height of over 1,200 feet, while further south, to the east of the village of Salisbury, is Barack M'Teth (1,300 feet), and Watawanchu Mountain (1,300 feet), and farther east in about the latitude of Watawanchu Mountain is Mt. Prospect[1] (1,460). This tongue of alternating schist ridges so sharply outlined, presents so much of unity in topographical and geological features as to be eminently suited to separate treatment. As the ridges are composed of the Riga and Everett Schists, the area is closely connected geologically with Mt. Washington. This paper is devoted to the consideration of

[1] To be distinguished from one of the northwest peaks of Mt. Washington which bears the same name.

the structure within this tongue-like area, which includes between twenty and twenty-five square miles. The field work was mainly done in 1888, though the southern portion of the area was revisited in 1891, when the writer was assisted by Mr. Louis Kahlenberg, and again in 1892 when he was assisted by Mr. H. J. Harris. The work has been in charge of Professor Pumpelly, then the head of the Archean Division of the U. S. Geological Survey.

Views of Percival and Dana regarding the area.—Though the map accompanying Percival's report does not indicate the schist areas within the area which is under consideration, he several times mentions them in the text. One is surprised to find how accurate were his observations and how correct his views regarding the area, notwithstanding the limited facilities and unsatisfactory condition of his survey. The following extracts from his report[1] contain the more important statements which he made having reference to this area.

"It (the limestone) is accompanied throughout with Mica Slate sometimes forming thin interposed beds, and at other times extensive ranges. The Mica Slate, in the vicinity of the limestone, particularly when interposed in thin layers in the beds of the latter, is very generally dark and plumbaginous, but occasionally light gray, as in the more extended ranges. These latter usually occupy high narrow abrupt ridges, sometimes quite isolated, and at other times in longer ranges, generally with an irregular outline." (Pp. 126–127).

"A coarse dark Mica Slate, veined or knotted with quartz, and often abounding in staurotides and garnets, occurs especially in the north part of the ridge bounding, on the west, the valley south of Lime Rock village, ..." (P. 127).

"The general surface of the valley, in the north part of Salisbury, in Canaan, and in the adjoining part of Massachusetts, is low and level, but traversed by ridges of Mica Slate, often high and abrupt, either isolated, or in long continuous ranges, the latter generally presenting a distinctly curved outline." (P. 129).

"Between these two branches[2] extends a series of Mica Slate ridges, continued north from the ridge bounding the valley at Weed's Quarry (Kl.) on

[1] Report on the Geology of Connecticut, by JAMES G. PERCIVAL, New Haven, 1842, pp. 124–130.

[2] Of the Housatonic Valley.

the west, in a very undulating course, and marked by several transverse depressions, to a high isolated summit,[1] adjoining the north line of the east of the North Ponds[2] (Salisbury)." (P. 129).

In a paper read before the American Association in 1873[3] Professor J. D. Dana quotes Percival as stating that the mica schist in which he found garnets in the township of Salisbury, is below the "Stockbridge or Canaan Limestone," but giving it as his own view that the schist is the overlying rock. This observation of Percival has considerable interest, for though the "Stockbridge or Canaan Limestone" has been shown to consist of two members, one of which is below and the other above the Staurolite-bearing rock, it is probable that Percival discovered a locality at which the Riga Schist comes out from below the Egremont Limestone.

On the map accompanying Professor Dana's paper entitled Taconic Rocks and Stratigraphy,[4] a number of schist areas are represented within the area here treated, which he correctly described to be, in some cases at least, "isolated within the limestone area,—as isolated as islands in a sea."[5] He mentions eleven of them in Salisbury and eight in the part of Sheffield township just north. He believed that there is but one schist horizon, which overlies the limestone, and described three localities, nearly or quite within the area studied, to sustain his views. These are, (1) the hill three miles north of Gallows Hill (locality 4, l. c., p. 213) where the schist "overlies the limestone"; (2) Turnip Rock (locality 5, l. c., p. 213) where schist overlies limestone in a shallow synclinal; and (3) Tom's Hill in Salisbury, which is described as a very flat trough of schist toward the north, but developing farther south into an overturned synclinal with its axis dipping east (l. c., p. 214). The observations made by

[1] Tom's Hill.

[2] Twin Lakes.

[3] On Staurolite Crystals and Green Mountain Gneisses of the Silurian Age, by J. D. DANA. Proc. A. A. A. S., 22d (Portland) Meeting, 1875, p. B25.

[4] American Journal of Science, Vol. XXIX., June, 1885.

[5] Amer. Jour. Sci., Vol. XXIX., March, 1885, p. 211.

the writer accord with those of Professor Dana in the second instance only, which relates to the upper or Everett schist member. As will be fully shown below, the other mentioned localities have a much more complicated structure than was supposed by Professor Dana.

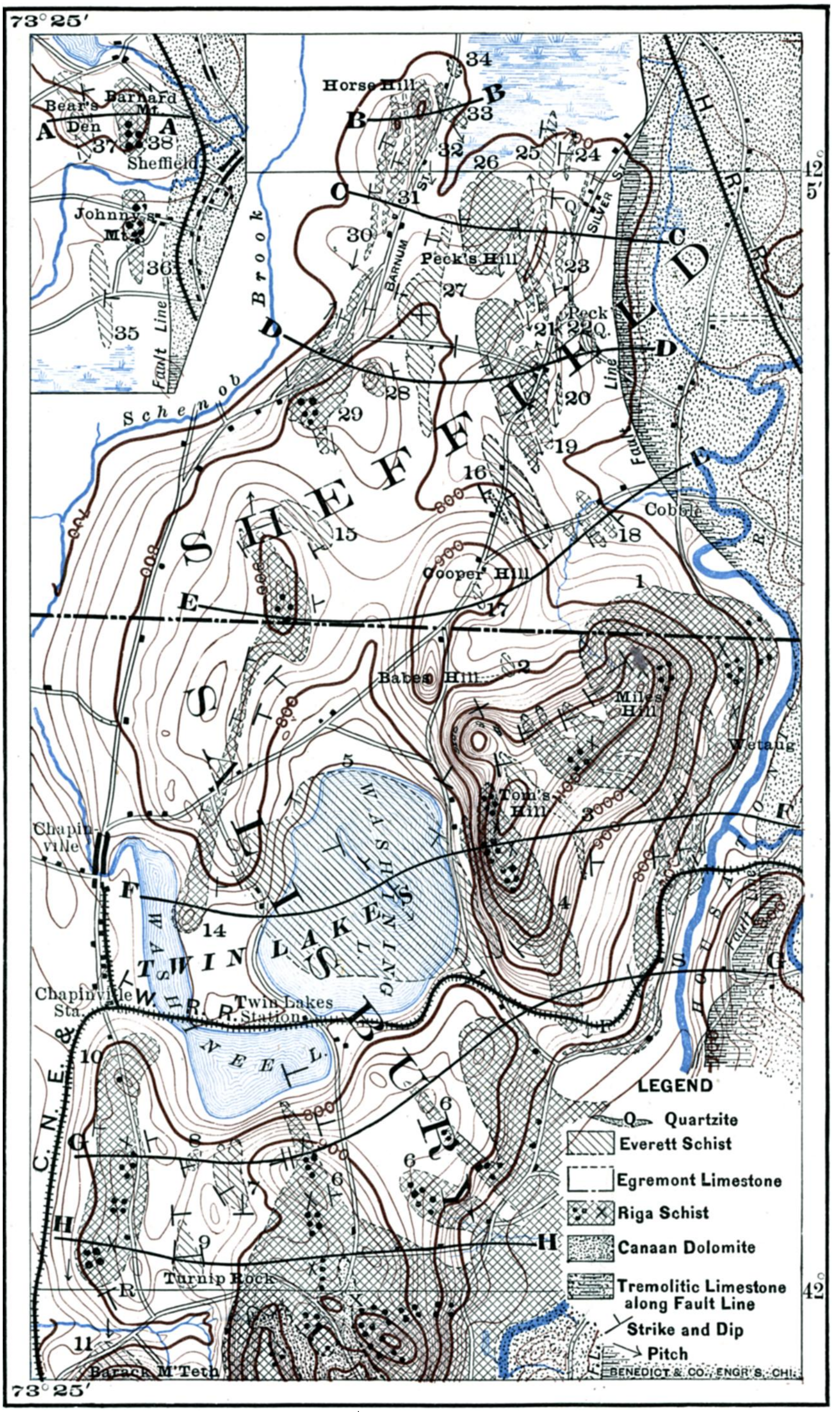
LITHOLOGICAL CHARACTERS OF THE HORIZONS.

As has already been stated, the horizons outcropping within this area all belong to the Mt. Washington series, viz.: The Canaan Dolomite, the Riga Schist, the Egremont Limestone, and the Everett Schist. The Canaan Dolmite seems to be for the most part a dolomite or dolomitic limestone, with more or less admixed quartz. A white pyroxene or salite is found to be common in it in the vicinity of Canaan, and in the belts extending east and northeast from that point. It has also been found at several localities in the vicinity of Lime Rock, but is only rarely seen west and southwest of that place. Tremolite is also found in this horizon, but as will be more fully explained beyond, this is largely restricted to a zone bordering the Housatonic River on the east. Masses of Canaanite are also found in this horizon, and as neither pyroxene nor tremolite has been found in the Egremont Limestone, their presence here is useful for purposes of identification.

The Riga Schist within this area has the characters which distinguish it on Mount Washington. In most of the ridges where it occurs, garnets alone or garnets and staurolites have been found in it. They are most abundant and of largest dimensions in the ridge south of Twin Lakes Station, the ridge south of Chapinville Station, in Tom's Hill and Mile's Hill, in Mt. Prospect (south of the area here mapped), and in Barnard Mt. and Johnny's Mt.[1] near Sheffield.[2] The mica is often a silvery

[1] These minerals were described from this locality in 1824 by Dr. Chester Dewey. Am. Journ. Sci., Vol. VIII., p. 7.

[2] Professor Dana has specially mentioned them from many of these localities. (l. c., p. 440). The increase in size of garnets and staurolite from Mt. Washington to the Housatonic, as described by him, has not been confirmed by this study. The largest that have been noted are from the south end of the ridge south of Chapinville Station.



GEOLOGICAL MAP OF PORTIONS OF SHEFFIELD, MASS. AND SALISBURY, CT.

sericite and considerable graphite is sometimes associated with it.

The Egremont Limestone resembles that found along the east base of Mt. Washington, its principal impurities being muscovite and quartz. It contains locally important layers of calcareous mica schist. In the vicinity of Twin Lakes, two distinct beds of the latter are made out, one immediately below the Everett Schist—a transitional zone—and the other lower down near the middle of the horizon. A third, less important and less constant, zone forms a transition from the Riga Schist to the Egremont Limestone. The upper of these layers forms the cap of Babe's Hill (northeast of Washining Lake). The middle layer is also found in the same hill along the southwest base, and the lowest layer may be seen above the Riga Schist at the first road-corner northeast of Chapinville. Graphitic phases are found as a transitional zone between this horizon and the overlying Everett Schist in the northeastern part of the area, particularly in areas 16 and 25.

The Everett Schist is not chloritic to any marked degree, as is so often the case on Mt. Washington, but is frequently sericitic, usually porphyritic from rounded eyes of feldspar, and frequently passes downward into graphitic schist.

EXPLANATION OF MAP.

The map which accompanies this paper (Plate V.) is based on the Sheffield and Cornwall sheets of the topographical atlas of the United States, by the U. S. Geological Survey, and is drawn on the same scale—1 : 62,500, or one inch to the mile. It overlaps by about one half mile the map which accompanies the Mt. Washington paper. To bring as much of the area as possible on the page, the narrow northern portion is placed in one corner, its actual position being roughly indicated by the positions of the Housatonic Railroad and the large marsh to the west of it. Fig. 5 also extends the map some distance to the south. The area covered by the Egremont Limestone is left blank, while the Riga and Everett Schist areas are shaded, the

former being the darker. The more important of the schist areas have been given numbers from 1 to 38. An attempt has been made to indicate the geological structure on the map by the introduction of such of the important dip observations as the scale of the map will allow, as well as small arrows which indicate the inclination of the trough and crest-lines (pitch). The course of an important fault is traced along the east bank of the Housatonic River.

GEOLOGICAL STRUCTURE OF THE AREA.

Since the beginning of the study of the Green Mountains by the Archean Division of the Survey, Professor Pumpelly has emphasized the necessity of making careful observations of the pitch of flexures, in order to arrive at a complete knowledge of the geological structure. Observations of this character have furnished the key to the structure within the area here studied. The crest lines of the folds show considerable and frequently changing inclinations, but the beds have withstood the stress to which they have been subjected in this direction without dislocation, as there is no evidence of any cross faults. The disturbance which came from the east, and which developed the flexures, has been so great as to overturn most of them, so that their axes dip east, and locally to cause a disruption with the production of rather steep thrusts of small displacement. An important dislocation has occurred along the course of the Housatonic River, which has carried the Canaan Dolomite over the newer beds exposed west of the river.

Structural features as shown in longitudinal sections.—A glance at the map will show that all the important ridges, with the exception of Barack M'Teth, Turnip Rock, and the Bear's Den, are formed of the Riga Schist. The fact that these ridges steadily increase in height in going southward, as well as the tongue-shaped outline of the area, indicates that the general pitch of the flexures is toward the north. This is in perfect accord with the fact that the folds in the main part of the Mt. Washington Mass have a northerly pitch. But although the general pitch within the area now under consideration is north-

erly, the local pitch[1] varies greatly both in degree and direction, and is as frequently southerly as northerly, as indicated by the arrows on the map. At the south base of Tom's Hill the southerly pitch varies from 30° to 50°, and on the road cutting across the north foot of Barack M'Teth, beautiful corrugations in the Everett Schist pitch southward at as steep an angle as 50°. These corrugations are unsymmetrical, the west limbs being the shorter and steeper. The local variations in pitch are strikingly indicated on the map by those ridges of schist which are arranged linearly in the direction of the prevailing strike, being cut off from one another by limestone. The minor changes in pitch are further shown by variations in width of the ridges. Thus we find along the western margin of the area three marked undulations in the crest-line of an anticlinal of Riga Schist trending north-northeast. The northernmost is essentially the double undulation of Horse Hill and area No. 29, then follows the area northeast of Chapinville (14), and the area south of Chapinville Station (10). Fig. 1, which is a longitudinal section along this line, shows besides the three main undulations just mentioned, a number of secondary waves of more or less importance. In Fig. 2 (A) these curves of the crest-line may be better observed. The manner in which this anticlinal ridge disappears near the southern limit of the map is shown in Fig. 1 of Plate VII. The

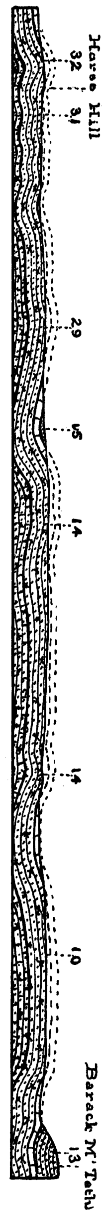


FIG. 1. Longitudinal section from Horse Hill to Barack M'Teth. Horizontal scale, one inch equals one mile; vertical scale, one-eighth inch equals five hundred feet.

[1] The pitch at any given locality is determined, either (1) by the direction in which the strike of the two limbs of a fold diverge in a synclinal fold or converge in an anticlinal fold; or (2), by the pitch of the plications in the schist. The harmony in direction and degree of inclination between the pitch of plications and that of the folds of which they are a part, was first suggested by Professor Pumpelly, and proven in the Greylock area. (Cf. T. Nelson Dale, Amer. Geologist, July, 1891).

ridge of Riga Schist is seen at A outlined from the surrounding Egremont Limestone by a dotted and dashed line. At B and C are seen Turnip Rock and Barack M'Teth, composed of Everett Schist. Between A and C the average strikes in the limestones are nearly east-west, and the dips (due entirely to pitch) about 30° south. Approaching Turnip Rock the strikes become northerly and the dips easterly, as the limestone mantles around the ridge A.

A second elevated area of the Riga Schist having three principal undulations in the direction of its prevailing strike,

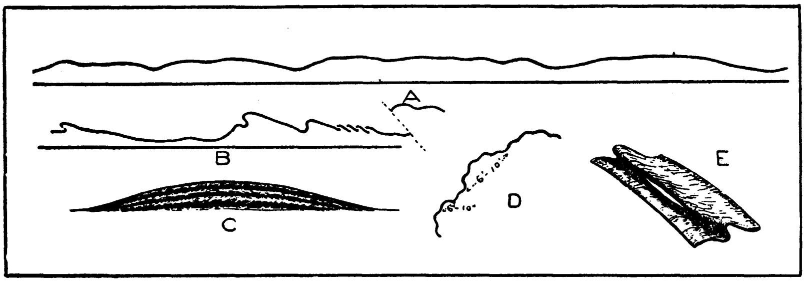
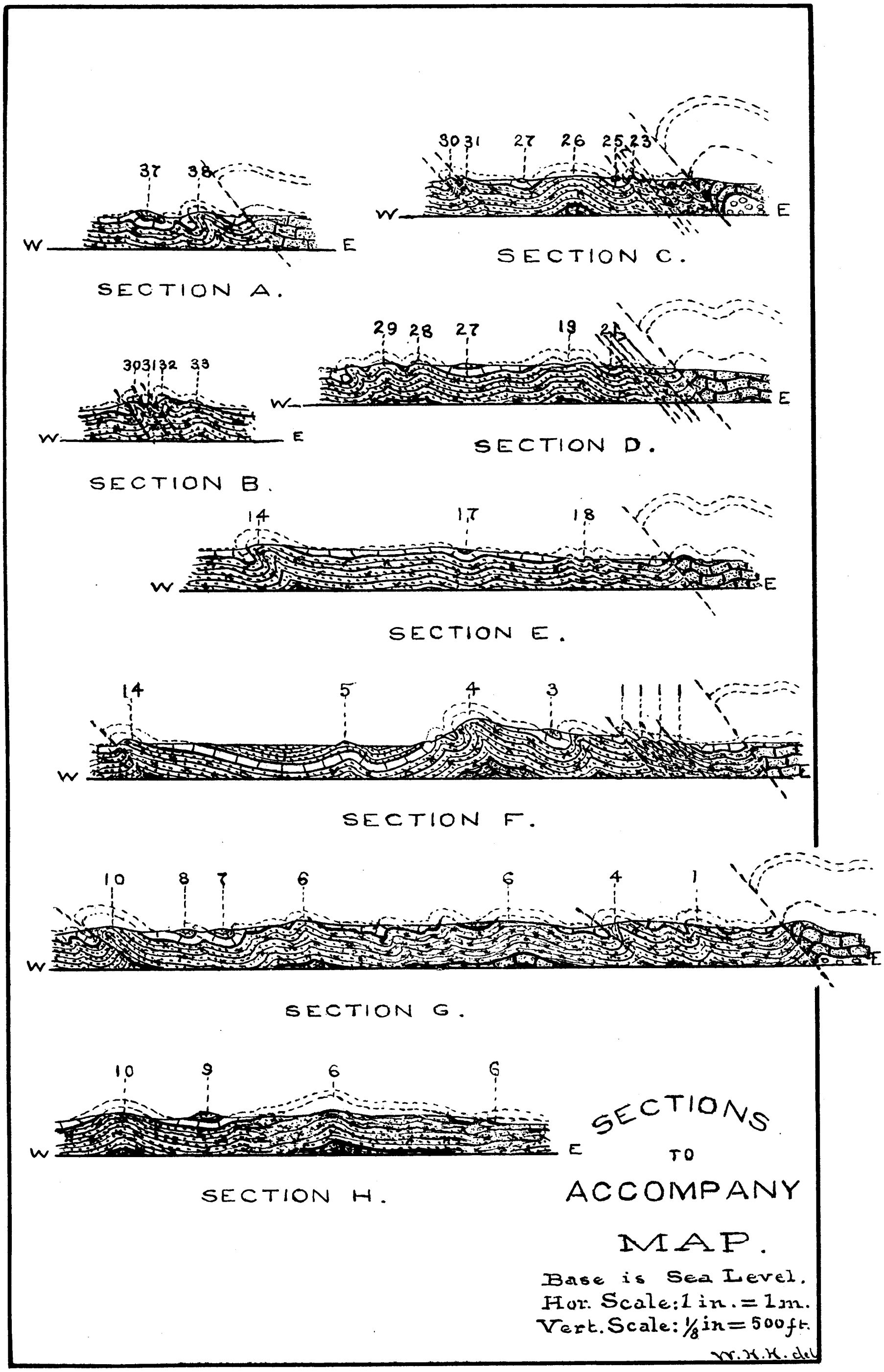


FIG. 2. Diagrams illustrating some of the structural features of the area studied. A, Flexures in crest-line of the western ridge of Riga Schist. B, Flexures in Tom's Hill and region to the west (from section F, Plate VI). C, Diagram showing the corrugated character of some of the smaller schist knolls near Salisbury. D, The same in section. E, Diagram showing the probable manner of development of small steep thrusts in the sharply folded region southeast of Tom's Hill, and in Horse and Peck's Hills.

corresponding with the three undulations of the western schist anticlinal, is traced along the eastern margin of the district. The northern of its three undulations brings to the surface in Peck's Hill, schist areas 26 and 19, and the accessory overturned and ruptured fold of areas 22–24; while the central undulation brings up in Miles Hill and Tom's Hill schist areas 1 and 4, and the southernmost undulation develops the extensive schist areas south of Washining Lake (Area No. 6). The schist of Peck's Hill disappears south of the swamp on the north base of the elevation, but the narrower eastern fold reappears north of the swamp in Johnny's Mount and Barnard Mount, where it, too, soon disap-


SECTION A.
SECTION B.
SECTION C.
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SECTION E.
SECTION F.
SECTION G.
SECTION H.
SECTIONS TO ACCOMPANY MAP.
Base is Sea Level.
Hor. Scale: 1 in. = 1 m.
Vert. Scale: 1/8 in = 500 ft.
W. H. H. del.

pears beneath the limestone as the most northerly outcrop of the Riga Schist. The southern limit of the central crest of the eastern undulation is at the south base of Tom's Hill, where the schist disappears through a southerly pitch varying from 35° to 50°, allowing the Housatonic River to take at this point a south-south-westerly course after being carried to the eastward by the unyielding schist mass of the hill. The minor undulations of the crest-lines of flexures within the northern part of this eastern ridge, are beautifully shown, not only by the areal relations and by divergence of strike observations, but also by the pitch of the plications (cf. arrows on map). Within the central undulation (Miles Hill), the same feature is indicated in the small basins of limestone which are entirely enclosed within the boundaries of the Riga Schist. The triple undulation of the western ridge of the district has a perfect parallel on the east. To the southwest of Tom's Hill just south of Washinee Lake appears an anticlinal of schist, which continues to rise and broaden in going south. The island in the lake is an anticlinal of the Egremont Limestone where it mantles over the ridge of schist. From below the schist anticlinal emerges the Canaan Dolomite near the southern margin of the map. As would be expected, the caps of Everett Schist which are found within the area studied, are widest opposite where the ridges of Riga Schist disappear, *i. e.*, where basins of quaquaversal synclinals are formed by the coincidence of longitudinal and transverse synclinals.

Structural Features as shown in transverse sections.—The nature of the flexuring within the area studied is indicated in the series of sections (cf. Plate VI). The types are the unsymmetrical fold with shorter and steeper western limb, indicating an easterly dipping axis, and the overturned or reversed fold with easterly dipping axis less steep than the first. The western limb of the sharper reversed folds has been ruptured, in some cases producing rather steep thrusts of small displacement. The hade of these faults is about 45°. The main flexures carry also subordinate systems of flexures. The areal geology of Horse Hill and Miles Hill in particular, shows that these properly secondary foldings

are corrugated by a tertiary system of small flexures, and examination of the plications at localities usually reveals even a quarternary system of minor foldings. Many of the small knolls near Salisbury present a surface something like the half of a muskmelon, except that a section, instead of resembling an epicycloid, would be more like a sine curve developed on an arc (cf. Fig. 2 (C). Figure 2 (D) illustrates this structure as seen in the anticlinal ridge No. 6 south of Twin Lakes Station, and in a number of small hills near Salisbury.

The Everett Schist occurs in caps or mantles which are for the most part shallow, nearly symmetrical, synclinals, as exhibited

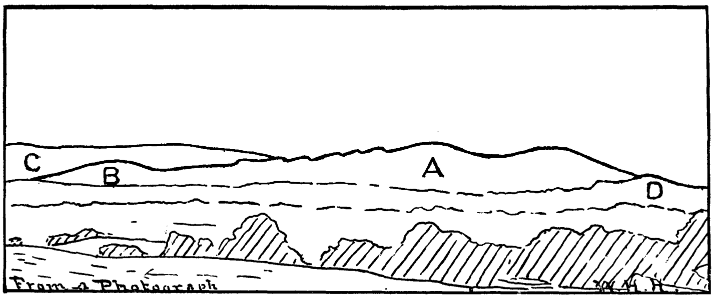

FIG. 3. View of Tom's Hill from the northwest, showing the serrated contour caused by the alternation of belts of schist and limestone. A, Tom's Hill. B, Northeast foot of Miles Hill. C, Canaan Mt. D, Babe's Hill.

in Turnip Rock (9), the cap on the southwest slope of Peck's Hill (27), and the Washining Lake Mantle (5), the latter being a double synclinal, as shown by the anticlinal ridge which forms the island in the lake.

Structure of Tom's Hill.—The doubled-peaked elevation east of Washining Lake is a compound anticlinal of Riga Schist, with two prominent crests appearing in Tom's Hill and Miles Hill respectively. These anticlinals, like most others in this region, are pushed over to the westward. A number of subordinate anticlinals, likewise compressed and overturned and here probably ruptured, are indicated on the map along the northern boundary of the Riga Schist by fingers of schist which protrude

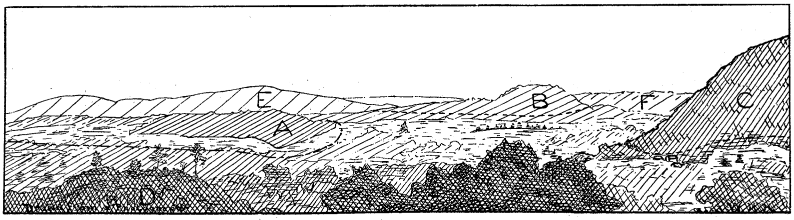

Fig. 1.

Fig. 2.

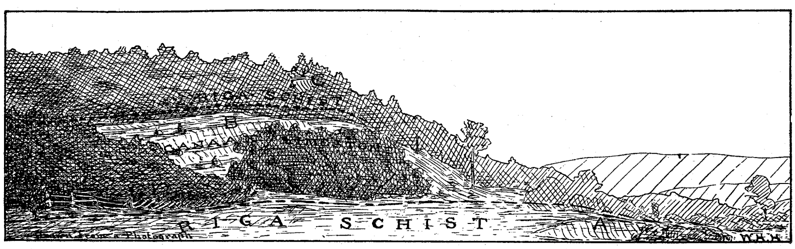

Fig. 3.

into the limestone, as well as by the serrated contour of the ridge when seen from the northwest (cf. Fig. 3). Between Tom's Hill and Miles Hill is a fold of Egremont Limestone overturned to the west and enclosing a core of the Everett Schist. The islands of limestone inclosed in the schist of the eastern flank of Miles Hill, are the result of frequent alternations of pitch in small reversed folds which for a short distance have been ruptured. A stereogram showing the surface of the schist before it had been cut away by erosion would here present the characters of a choppy sea (cf. Fig. 2 E.) These long alternating belts of schist and limestone on the southeast foot of the hill northwest of the railroad bridge (V on map), are indicated topographically by a series of low, sharp ridges which have gradual east and steep west slopes (cf. Plate VII., Fig. 2). Farther south, near the railroad bridge, the several schist ridges become fused together and show more symmetrical undulations. The dips are here uniformly east at angles varying from 30° to 50°, and the closeness with which the belts are crowded together allows insufficient room for the full thickness of the Egremont limestone of this vicinity. The indications therefore are that the folds have here been so sharply compressed that the beds have found relief in a slight dislocation or thrust, producing a structure best illustrated in Fig. 2 (B), to which Suess has applied the term *Schuppenstruktur*,[1] and which I would term *weatherboard structure*. It is probable that both the throw and displacement of these dislocations is very slight, being greatest where the crest-lines show an anticlinal structure and least where they show a synclinal structure. An attempt has been made to show the nature of these dislocations as they are supposed to occur on the southeast flank of Miles Hill (Fig. 2 E.) Owing to the covering of earth in the valleys, the course of the fault is not exposed. The only locality where the beginnings of such a

[1] EDUARD SUESS: Das Antlitz der Erde, Vol. I., p. 149.

Gosselet has used *structure ecailleuse* (Ann. soc. geol. du Nord, Vol. XII., 1885, p. 197) for similar structures, and Margerie recommends *structure imbriquée* (Margerie et Heim, Les dislocations de l'ecorce terrestre, Zürich, 1888, p. 82).

fault have been actually observed in the rock exposure, is on the railroad a half mile southeast of the locality just described (S on map). The nature of the flexuring at this point is made

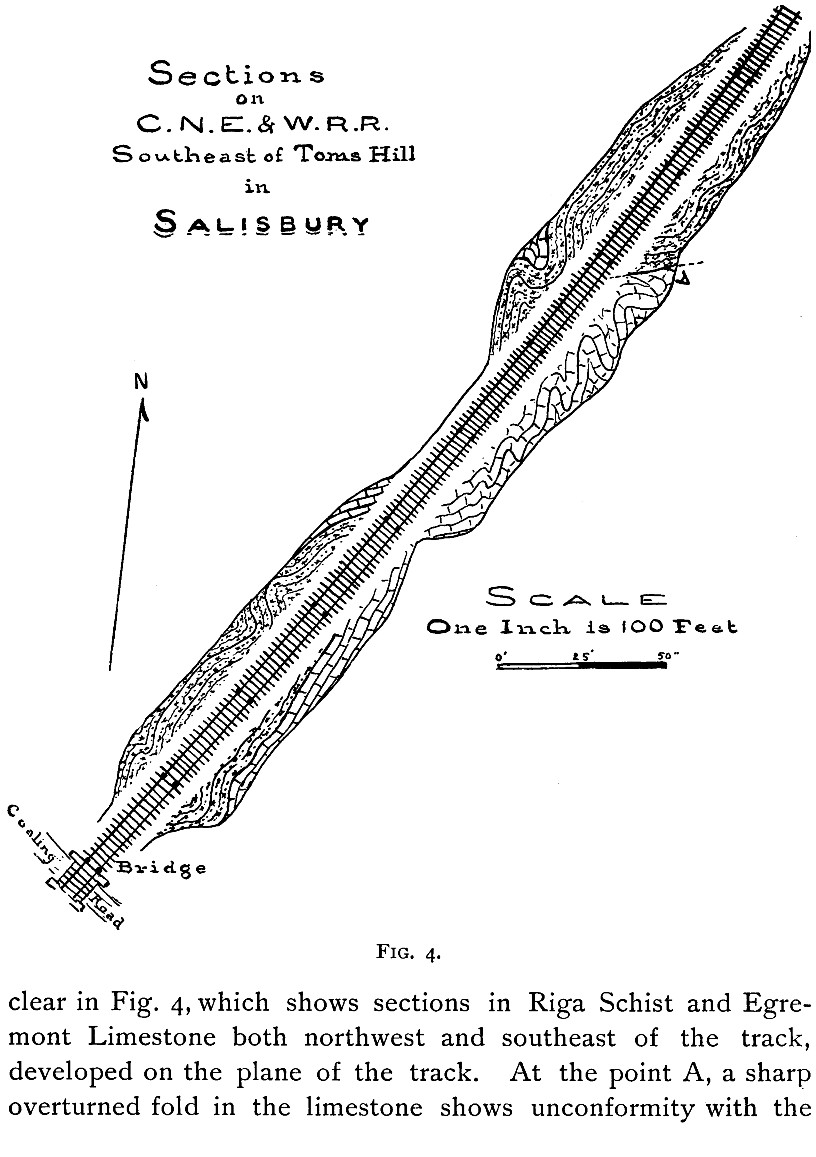

FIG. 4.

clear in Fig. 4, which shows sections in Riga Schist and Egremont Limestone both northwest and southeast of the track, developed on the plane of the track. At the point A, a sharp overturned fold in the limestone shows unconformity with the

underlying schist through a slight fault. The marked difference between the sections north and south of the track is due to steep southerly pitch.

The great Housatonic Fault.—Enough has been presented in the Mt. Washington paper and in the present discussion, to show that the limestone of this region is divisible into two horizons—the Canaan Limestone or Dolomite, lower than the Riga Schist, and the Egremont Limestone above that schist. Additional evidence might be brought forward, if it were necessary, from the region lying to the southward in the vicinity of Limerock. As has also been stated, the Canaan Dolomite, particularly in the vicinity of Canaan and in the valleys east and northeast of there (Monterey, Mill River, Clayton, East Canaan), abounds in crystals of white pyroxene, which has never as yet been found in the Egremont Limestone. Hence this mineral has a certain value for purposes of identification, comparable with that of the garnet and staurolite of the Riga Schist. Masses of Canaanite also occur in it though absent from the Egremont Limestone. Early in this investigation, when the possibility of a differentiation of the limestone was only suspected, this lithological peculiarity was noted, but as the pyroxene-bearing limestone to the eastward did not seem to be separated from the pyroxene-free limestone to the westward by any areal break, the question of divisibility was left open. It was, however, observed that the Housatonic river roughly outlined the westward extension of the pyroxene-Canaanite rock to the north of the interstate boundary. Another striking feature of this line is a ridge more or less pronounced, having its course along the banks of the river. In the southern half it follows the east bank of the river, but crosses it at the small hill called the "Cobble," just northeast of Miles Hill, and to the north of that point borders the west bank.[1] This ridge is composed of a rock which has not been found elsewhere in the region. It is a dolomite abounding in tremolite and containing layers of quartzite and quartzitic dolomite. Par-

[1] The southern portion of this ridge (that east of the river) is the ridge mentioned as Canaanite on page 126 of Percival's report.

ticularly along its west margin the rock is found to be seamed with vein quartz in every direction. These characters have not been found outside of the ridge, which is rarely over a quarter of a mile wide. The well known greenish tremolite of Canaan is from Maltby's Quarry at the extreme south of this ridge. The rock was provisionally designated the tremolitic quartzitic limestone and its area was mapped. Sudden changes in the strike and dip of the beds were found to be particularly common in this ridge.

Now that the stratigraphy has been determined, there seems to be no reason to doubt that this ridge marks the course of a great reversed fault, which in its upthrown limb brings the Canaan Dolomite against the newer beds in its western or underthrown limb. The development of tremolite is ascribed to the profound shearing which has occurred along the fault plane, and the ragged dolomite filled with quartz veins to fracturing or crushing and recementing of the fragments by the silica of waters which have percolated along the fractures—in other words, it is a fault breccia. The ridge has survived as a topographical feature, because of the framework of quartzite and vein quartz and the imbedded crystallized silicates in the dolomite. The fault line may be followed by these characters from near Sheffield village to Maltby's Quarry, northwest of South Canaan, a distance of about ten miles. To the northward it probably connects with some of the faults of Vosburgh Hill, but its course here has not been followed. To the south of Maltby's Quarry the fault is followed in the direction of the prevailing strike to the northeast base of the Cobble,[1] which base it coincides with for some distance. This, as will be more fully shown later when that area is described, is indicated by the Cambrian Quartzite being absent, the actual contact of gneiss and apparently overlying Canaan Dolomite being exposed. On the west base of this narrow hill, the quartzite is present separating the gneiss and dolomite, and it also runs around the north end of the hill to

[1] At South Canaan. This is not the Cobble already referred to and located on the map (Cf. Plate V.)

stop abruptly at the northeast base. The well known white pyroxenes of Canaan come from the dolomite adjacent to the

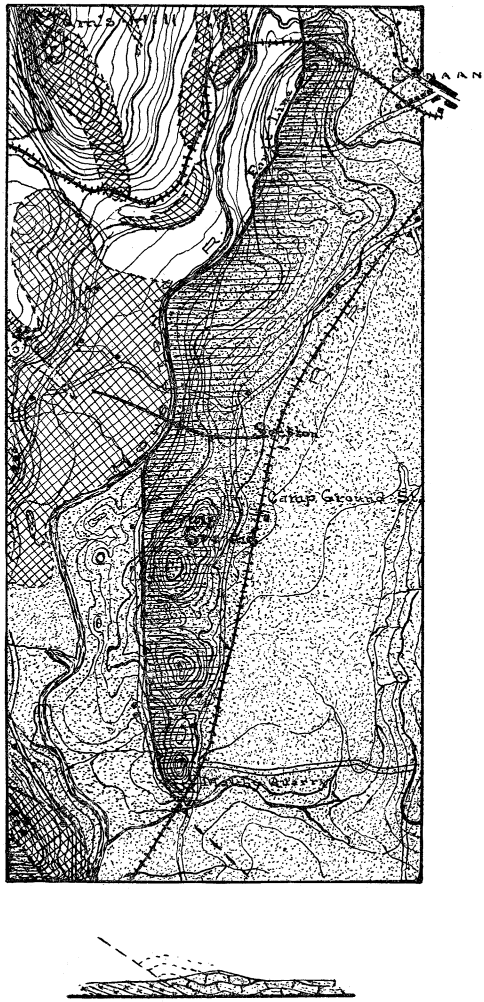

FIG. 5. Map and section of the vicinity of the Housatonic Fault, southwest of Canaan village. Scale and legend the same as in Plate V.

fault line, on the road running immediately at the east base of this hill, and are much the largest that have been found in the

region. The fault probably extends a considerable distance farther to the southward but its course has not yet been traced. The northern course of the fault is indicated on the map.

Starting at the Maltby Quarry, where the surface rock on both sides of the fault line is Canaan Dolomite, and going northward, to the west of the fault line the generally northerly pitch carries the beds lower and lower so that Egremont Limestone is met before Sheffield is reached. On the east, however, no such pitch exists, and Canaan Dolomite is the surface rock for the entire distance. The Riga Schist has not been found in actual outcrop abutting against the fault plane and separating the two calcareous horizons, but this is explained by the absence of outcrops along the river valley. The map and section in Fig. 5 are introduced to indicate how the Riga Schist is believed to meet the dolomite at the fault line. This map is drawn on the same scale and has the same legend as Plate V. An examination of Plate V. will show how the hard Riga Schist of Miles Hill has caused a deflection of the Housatonic River to the eastward in that vicinity. The important easterly deflection which exists in the vicinity of the Canaan Camp Ground (cf. Fig. 5) is believed to be caused in the same way. The low area between the river and the road to the west of this bend is bare of outcrops, but Riga Schist is encountered on the road and covers a considerable area west of it. On the east of the river at this bend the tremolitic Canaan Limestone is encountered almost at the river's bank. There seems, therefore, reason for believing that in this vicinity the fault follows the river and that the two rocks abut against one another at the fault plane.

To the southward of the Maltby Quarry the fault is of a somewhat exceptional character, since the prevailing northerly pitch of the beds to the west of the fault line brings beds lower than the dolomite (First Cambrian Quartzite and then Cambrian Gneiss) to the surface in the Cobble. The upper limb of the fold is no longer the overthrown limb, but it is forced to a lower position. We have here, then, an example of a fault, which at the north is a rather steep overthrust with Canaan Dolomite over

Egremont Limestone, and at the south end a reversed fault with the same rock over Cambrian Gneiss. It follows that the throw varies most widely. At some fulcrum point, which must be near the Maltby Quarry, this is practically *nil.* To the north of that point, the western limb has been downthrown an amount which steadily increases in going north, till in the vicinity of Sheffield it can hardly be much less than a thousand feet. To the southward of the Maltby Quarry, the western limb has been upthrown and the amount of this upthrow at the Cobble must be several hundred feet.

The occurrence of two very thin quartzite lenses, which follow a line parallel with the fault line along "Silver Street" in Sheffield (Cf. Plate V.), is reason to believe that two secondary faults there run parallel to the main fault.

Additional evidence of the main overthrust is the occurrence of numerous very large boulder-like masses of the tremolitic quartzitic dolomite, resting on the Riga Schist to the east of the road on the northeast flank of Miles Hill. It might be argued that they are of glacial origin, since the direction of glacial movement in this section is favorable, but they could only have come from a point just across the river, and such masses are not distributed over the area to the southwest. Such masses are, however, found in abundance along the eastern side of the overthrust for almost its entire length, and it therefore seems most probable that they are fracture blocks produced in the faulting, which have rounded through weathering, and as degradation has gone on, have settled down upon lower beds of the mother rock, and to some extent also upon the Riga Schist west of the river.

This reversed fault presents some analogies with the overthrust faults of the southern Appalachians described by Hayes,[1] and those in New York described by Darton[2], but the fault plane

[1] The Overthrust Faults of the Southern Appalachians, by C. W. HAYES. Bull. Geol. Soc. Am., Vol. 2, pp. 141-154, pls. 2-3. Cf. also Willis and Hayes, Am. Jour. Sci. (3) XLVI, pp. 257-268. Oct., 1893.

[2] On two Overthrusts in New York, by N. H. DARTON. Bull. Geol. Soc. Am., Vol. 4, pp. 436-439.

has here a steeper hade, so that the older dolomite has been carried only a short distance over the newer beds.

Metamorphism along the fault.—Of considerable interest is the recrystallization which has taken place along the fault plane. The tremolite of the Housatonic ridge, and the large pyroxene crystals of the east base of the Cobble at South Canaan, must be explained in this way. The ragged quartzitic dolomite rock which characterizes the Housatonic ridge throughout its entire extent and is not found elsewhere in the region, is believed to owe its characters to a crushing along the fault and a recementing of the fragments by a vein quartz—it is in other words, a fault breccia.

In the vicinity of the great thrust planes of the Northwest Highlands of Scotland, which have been so carefully studied by Geikie, Peach and Horne, and their associates of the Geological Survey of Scotland[1], schistose structure and new minerals have been developed by the shearing, micas, hornblende, actinolite and garnet being produced in this way[2]. Another instance of this sort is furnished by the overthrusts of the Rocky Mountains along the line of the Northern Pacific Railway.[3] These thrusts have likewise produced metamorphism of the beds along the thrust planes, argillaceous layers being made schistose and limestones being whitened and cracked.

Thickness of the Egremont Limestone.—In the Mt. Washington paper, I have shown that the thickness of the Egremont Limestone in the southern portion of the summit plain is less than one hundred feet, and that a little farther south it probably dies out altogether. In the northern portions of that area, where it

[1] The Crystalline Rocks of the Scottish Highlands, by ARCH. GEIKIE, B. N. PEACH, and JOHN HORNE. Nature, Vol. XXXI., pp. 29-35, Nov., 1884.

Report on the Recent Work of the Geological Survey in the Northwest Highlands of Scotland, Based on the Field Notes and Maps of Messrs. B. N. Peach, J. Horne, W. Gunn, C. T. Clough, L. Huxman, and H. M. Cadell. Communicated by A. GEIKIE. Quart. Jour. Geol., Soc., London, Vol. XLIV., pp. 378-441, 1888.

[2] Nature, Vol. XXXI, p. 35.

[3] Report on the Geological Features of a Portion of the Rocky Mountains, by R. G. MCCONNELL. Ann. Rep. Geol. Surv. Canada, (New Series) Vol. II., 1886, p. D34.

attains a greater thickness, no measurements could be made, though it can safely be said that it does not exceed a few hundred feet. The relations made out in the area now under consideration, allow of a thickness which agrees well with that found in Mt. Washington. A locality which illustrates this will be here briefly mentioned, because the structure is so simple as to afford reliable results. The locality is a knoll called Pine Hill, lying at

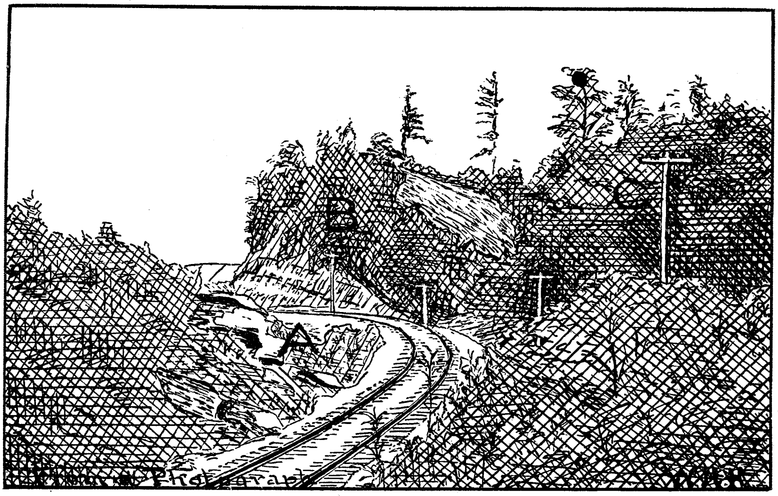

FIG. 6. View of Pine Hill on the southeast flank of Tom's Hill, seen from a point to the west. A, Riga Schist. B, Pine Hill composed of Egremont Limestone. C, Approximate position of cap of Everett Schist.

the southeast foot of Tom's Hill south of the railroad. The dips are low, due entirely to pitch, and the thickness of the limestone less than 100 feet. (This locality is marked P on the map). North of the track (A in Fig. 6) is seen the Riga Schist pitching south at an angle of about 35°. Across the track and a little farther east is Pine Hill (B), composed of a pure, white limestone dipping conformably over the schist, and capped on its south slope by a thin layer of the Everett Schist. The outcrops of this rock are hidden in the view, but their approximate position is shown by C. The thickness of the Riga Schist and the Canaan Dolomite have

not been measured. The former probably has a thickness of much less than a thousand feet. A locality where the Canaan Dolomite appears below it in the core of a fold, is shown in Plate VII., Fig. 3.

Conclusions.—Some of the results of this study may be summed up in the following statements:

I. The district is geologically closely connected with Mt. Washington, and contains the same horizons, viz: Canaan Dolomite, Riga Schist, Egremont Limestone, and Everett Schist. For the most part the same general lithological features characterize these horizons as on Mt. Washington. Pyroxene is a characteristic mineral in the lower but absent from the upper calcareous member. Garnets and staurolites are abundant in the lower but absent from the upper schist member. Locally important beds of calcareous schist occur in the Egremont Limestone. The Everett Schist differs from much of that of Mt. Washington in being essentially non-chloritic. The Egremont Limestone has a thickness of less than 100 feet in the southern part of the area.

II. The tongue-like outline of the area containing schist exposures is due to a general northerly pitch of the flexures to the west of the Housatonic River, though the local pitch of these flexures varies greatly and is as often south as north. Most of the prominent ridges are anticlinals of the Riga Schist, the few areas of Everett Schist being synclinals and largest where basins are formed by a coincidence of longitudinal and transverse synclinals. The schist areas exhibit an arrangement in four[1] east and west belts having each a width of about two miles, as the result of four marked undulations in the crest lines of the flexures. Particularly toward the north these belts are further subdivided by a secondary series of undulations a half mile or more in width, and a tertiary series of yet smaller waves can in some cases be made out at localities. These facts show that the area has been subjected to compression in a north and south direction,

[1] (1) Bear's Den, Barnard Mt., and Johnny's Mt.; (2) Horse Hill, Peck's Hill, etc.; (3) Northern Chapinville area, Tom's Hill, and Miles Hill; (4) Southern Chapinville area, and area No. 6.

as well as in an east and west direction. The compression from the north and south has produced no dislocation, as no transverse faults have been discovered.

III. The rocks of this area have been very sharply folded. The types of folds are the unsymmetrical, with short and steep western and longer eastern limbs, and the overturned and sharply compressed fold with an easterly dipping axis. Reduced and ruptured underthrown limbs are not uncommon, but the evidence is that the extent and the throw of these minor faults is very slight. On the southeast flank of Tom's Hill this has produced the structure which Suess has called *Schuppenstruktur*. I would suggest, as an English equivalent of this term, *weather-board structure*.

IV. An important reversed fault, which has been termed the Housatonic Fault, has a northerly course along the eastern border of the area of schist ridges. Its course very nearly coincides with that of the Housatonic River for a considerable distance. The fault is traced from near Sheffield village to beyond South Canaan, a distance of about twelve miles. North of the Maltby Quarry it has the characters of an overthrust which increases in throw in going north, owing to the northerly pitch of the beds to the west. This has carried the Canaan Dolomite of the eastern or normal limb over the newer Egremont Limestone and Everett Schist of the western reversed limb. South of the Maltby Quarry the western limb has been upthrown, bringing Cambrian Quartzite and Gneiss against the dolomite. The dolomite has been extensively crushed and metamorphosed along the fault plane. Tremolite and white pyroxene have been extensively developed in the vicinity of the fault plane, and vein quartz has cemented the dolomite fragments together, producing a fault breccia.

It is very probable that the rapid alternations of pitch which characterize this area are not altogether unusual. It is only rarely, however, that the areal relations shed so much light upon the form of the crest lines and trough lines of folds. What has been set forth will, I think, show that evidences of general

pitch, to be reliable, must be based on observations made over a considerable area.

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EXPLANATION OF PLATES.

PLATE V.—Geological Map of portions of Sheffield, Mass., and Salisbury, Conn., based on the Sheffield and Cornwall sheets of the Topographical Map of the United States by the U. S. Geological Survey. Scale 1 : 62,500.

PLATE VI.—Series of Geological Sections to accompany Plate V. Their location is indicated on the map (Plate V.) Horizontal Scale: one inch equals one mile. Vertical Scale: one-eighth inch equals five hundred feet.

PLATE VII.—FIG. 1. View showing the southern termination of one of the longitudinal undulations of the western schist anticlinal, as seen from the west. A, Southern limit of a ridge of Riga Schist (No. 10). B, Turnip Rock (Everett Schist). C, Barack M'Teth (Everett Schist). D, Knoll of Riga Schist. E, Tom's Hill in the distance. F, Ridge No. 6 (Riga Schist). The dotted and dashed line shows the approximate boundary between the Riga Schist and the Egremont Limestone, and the dotted line the approximate boundary between the Egremont Limestone and the Everett Schist.

FIG. 2. View of schist ridges separated by belts of limestone at the southeast base of Tom's Hill near the railroad bridge. A, B, C, Schist ridges. D, Slope of Tom's Hill where a fourth schist belt is hidden in the trees.

FIG. 3. Canaan Dolomite occupying the core of an anticlinal of Riga Schist at the south end of area No. 6. The view looks southeast. A, Outcrop of Riga Schist. B, Canaan Dolomite. C, Riga Schist.